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(54) **LINE CAPTURE DEVICES FOR UNMANNED AIRCRAFT, AND ASSOCIATED SYSTEMS AND METHODS**

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**B64F 1/04** (2006.01)

**B64C 39/02** (2006.01)

(52) **U.S. Cl.**

CPC ..... **B64F 1/04** (2013.01); **B64C 39/02A** (2013.01); **B64C 2201/182** (2013.01)

(58) **Field of Classification Search**

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See application file for complete search history.

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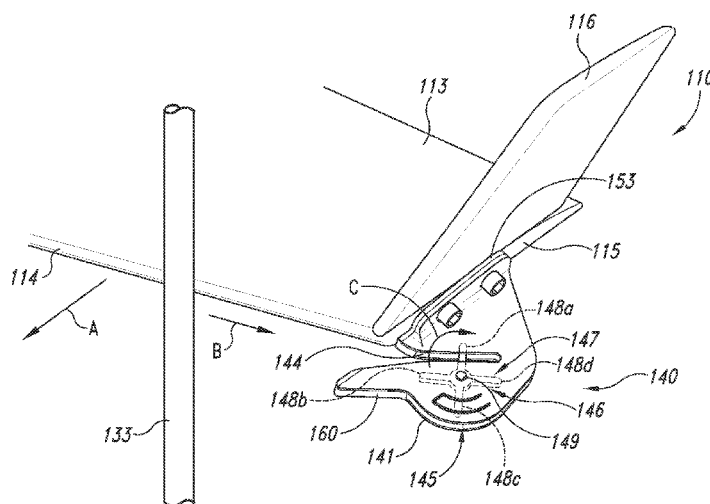
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(57) **ABSTRACT**

Line capture devices for unmanned aircraft, and associated systems and methods are disclosed. A system in accordance with a particular embodiment includes a line capture device body having a line slot with an open end and a closed end. A retainer is positioned proximate to the line slot and has a rotor with a plurality of rotor arms positioned to extend at least partially across the line slot as the rotor rotates relative to the body. A joint rotatably couples the rotor to the body, and a ratchet device is operably coupled to the rotor to allow the rotor to rotate in a first direction and at least restrict the rotor arm from rotating in a second direction opposite the first. In other embodiments, the retainer can include other arrangements, for example, one or more wire-shaped elements.

**19 Claims, 8 Drawing Sheets**



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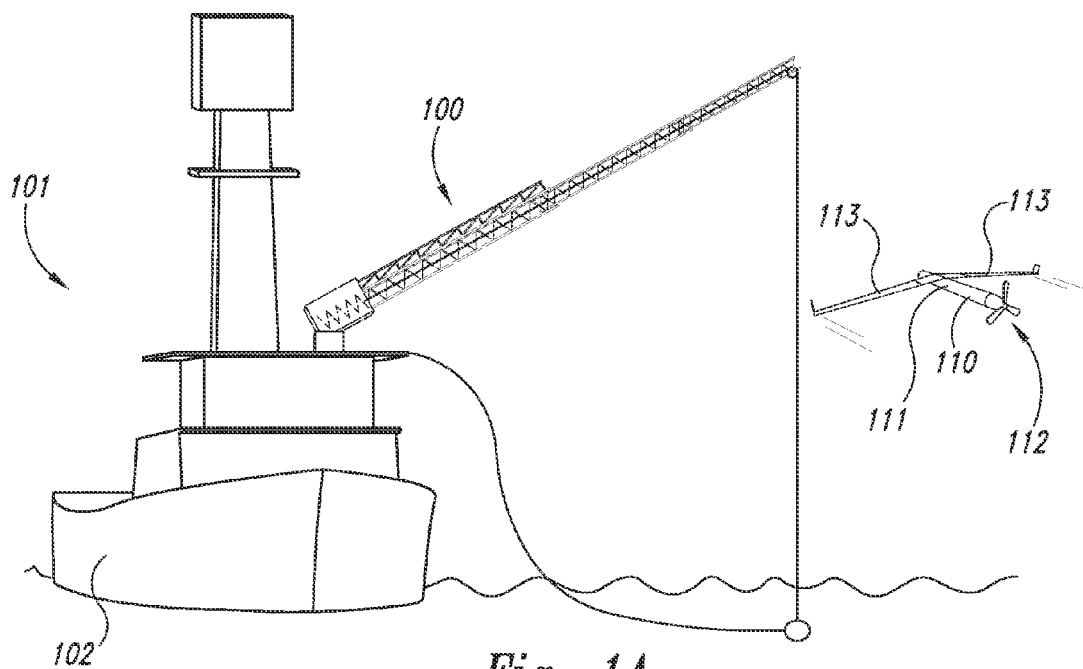


Fig. 1A

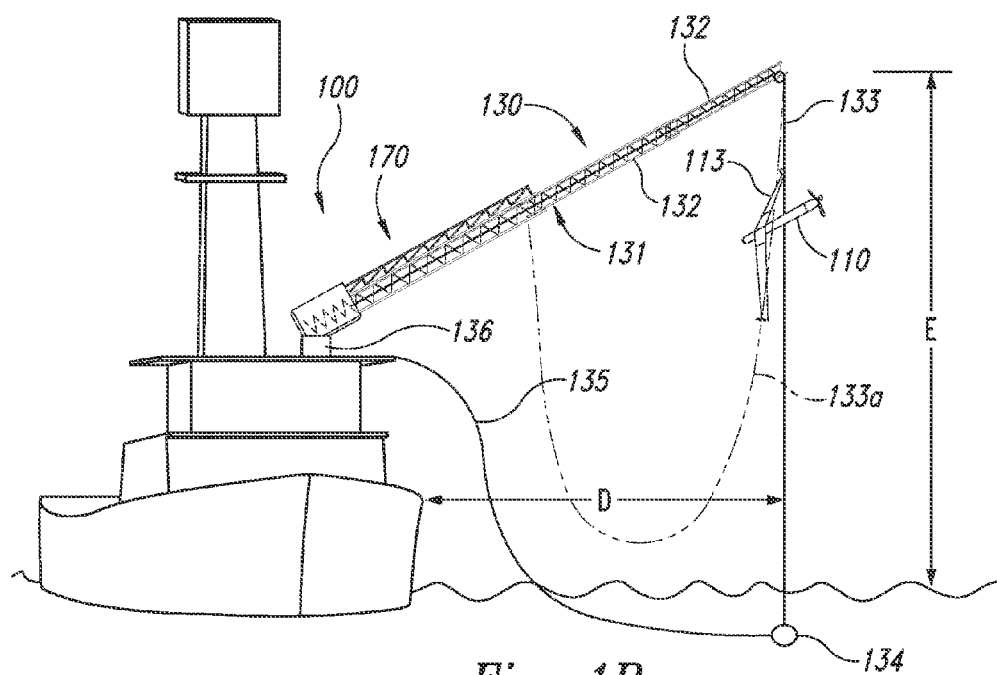
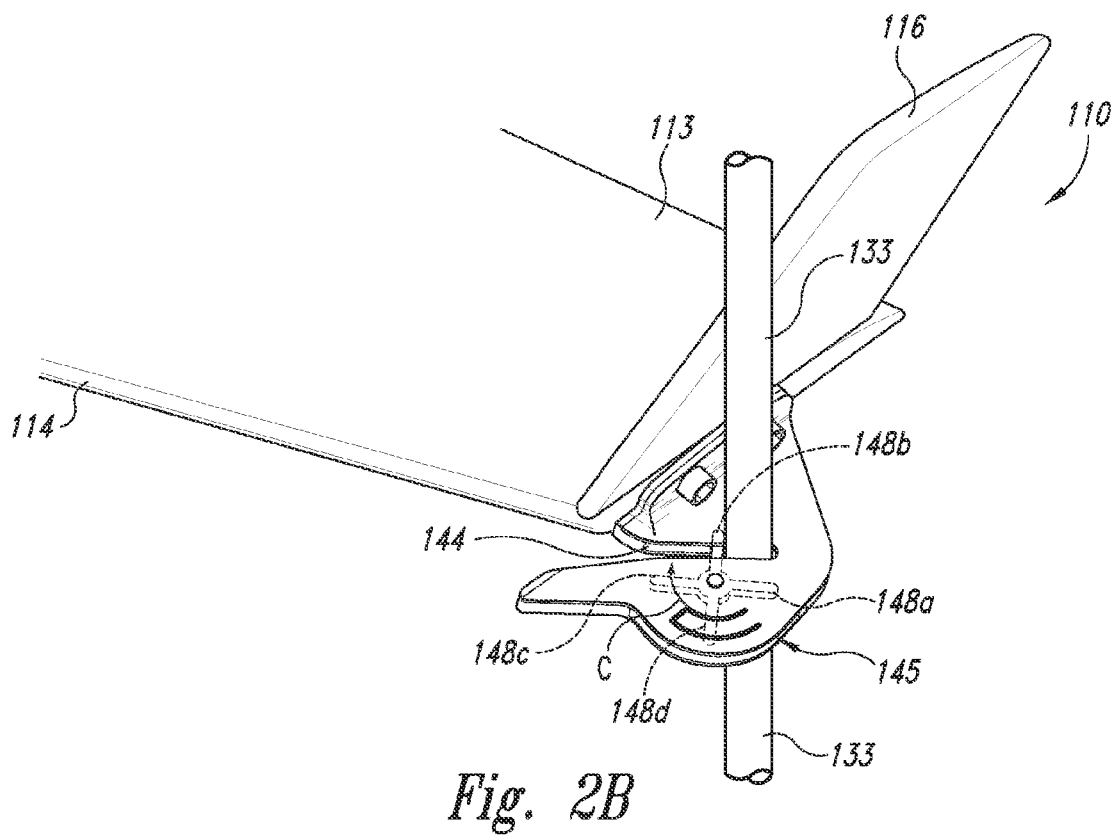
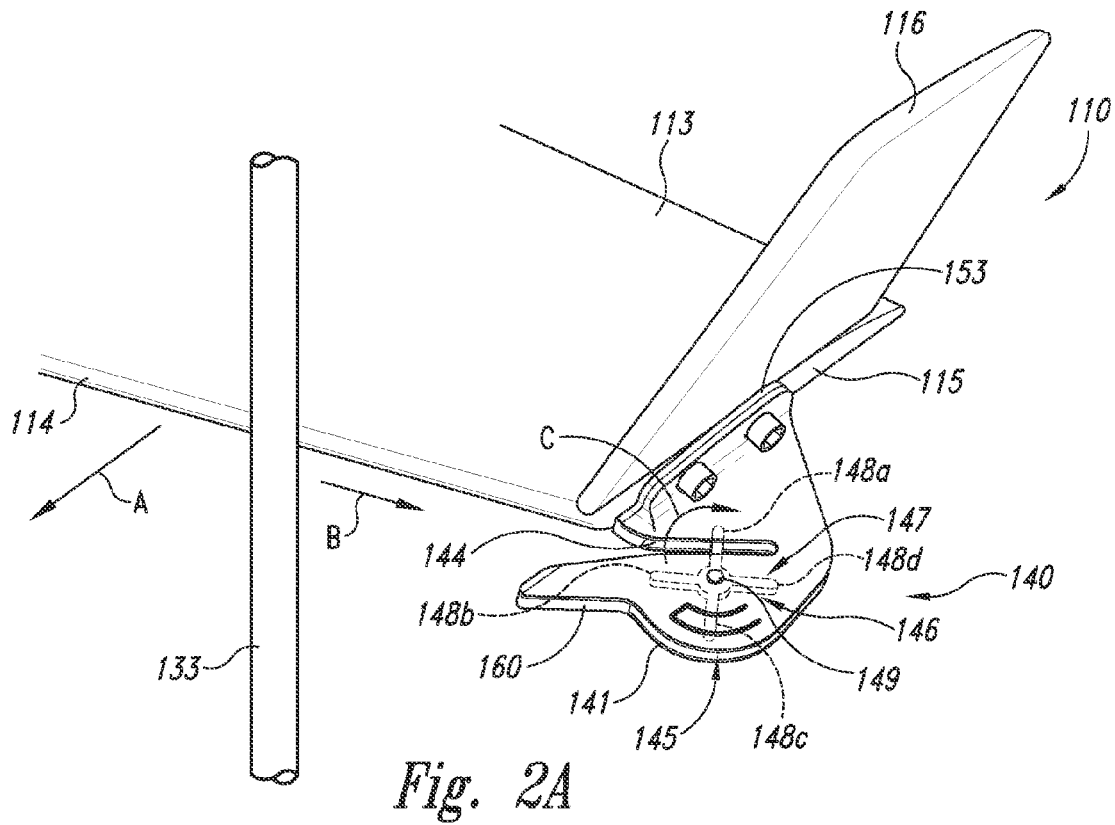
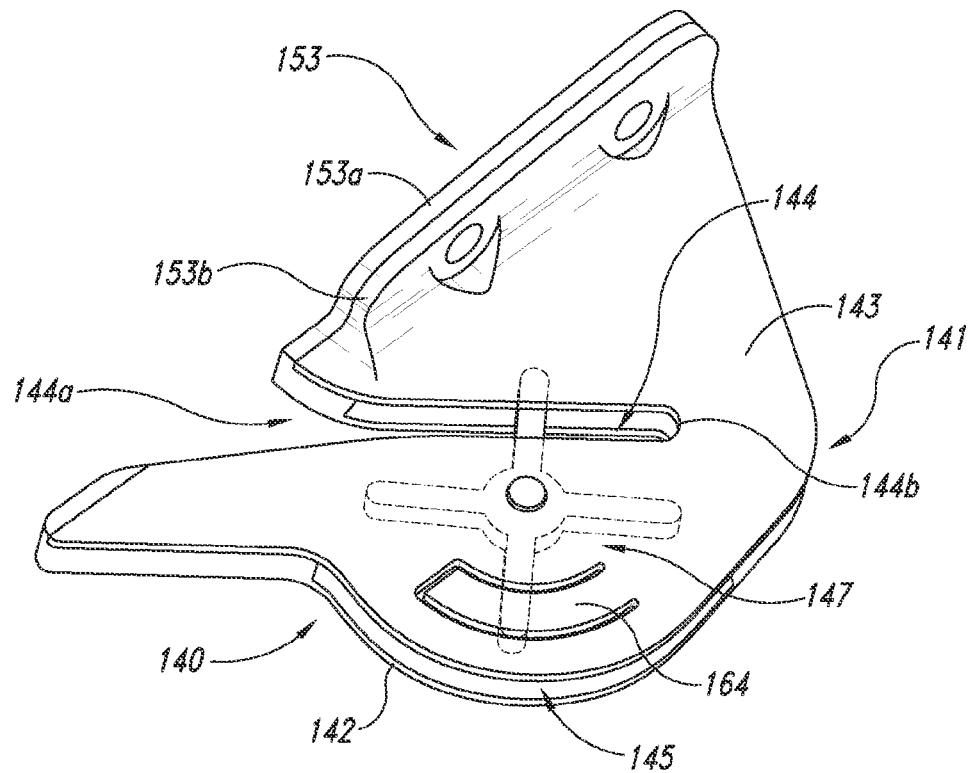
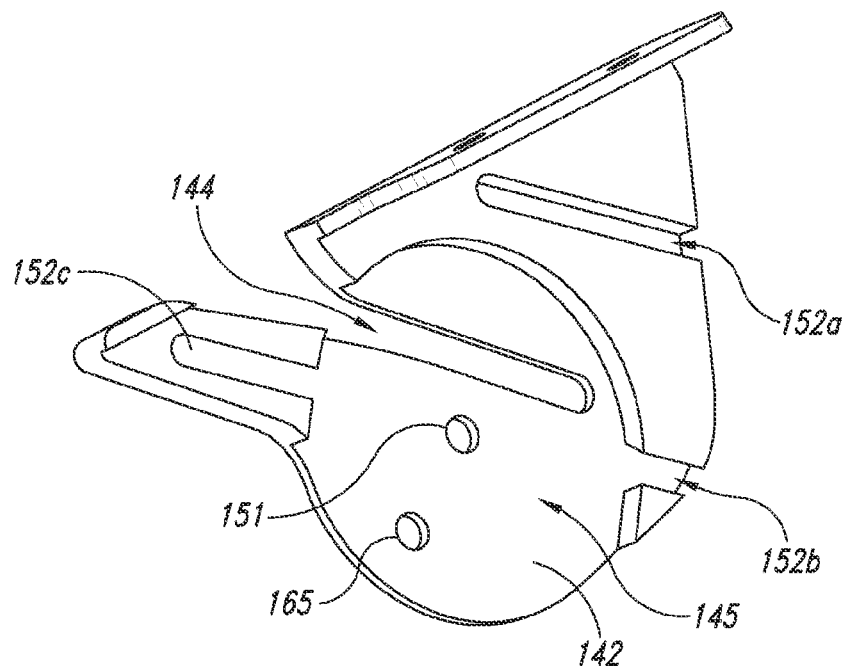


Fig. 1B

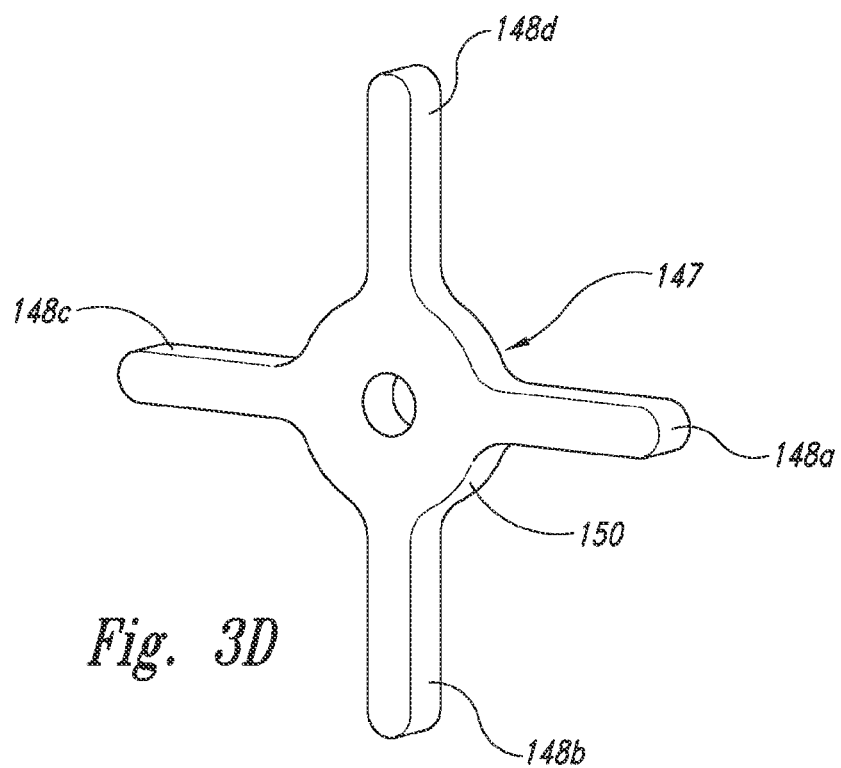
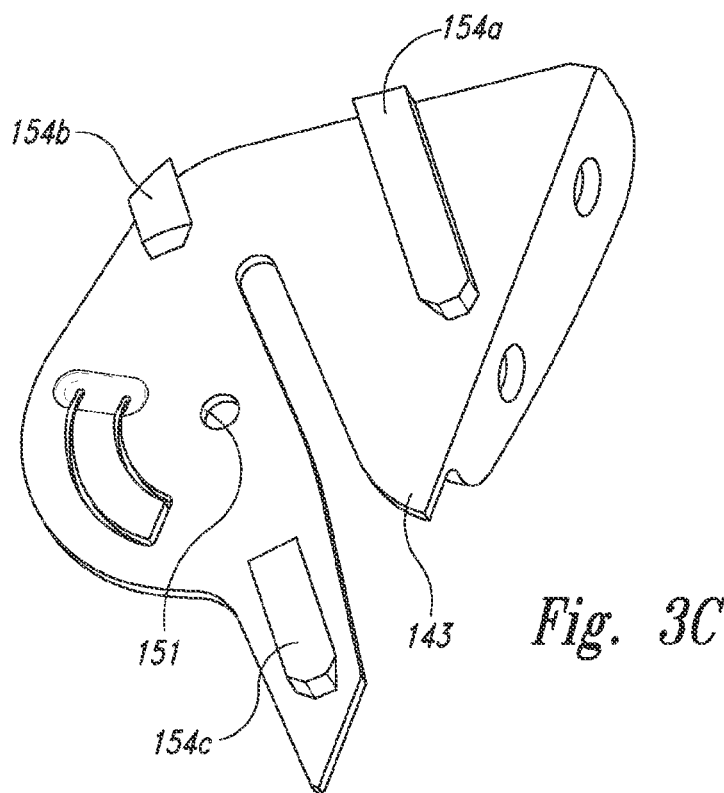




*Fig. 3A*



*Fig. 3B*



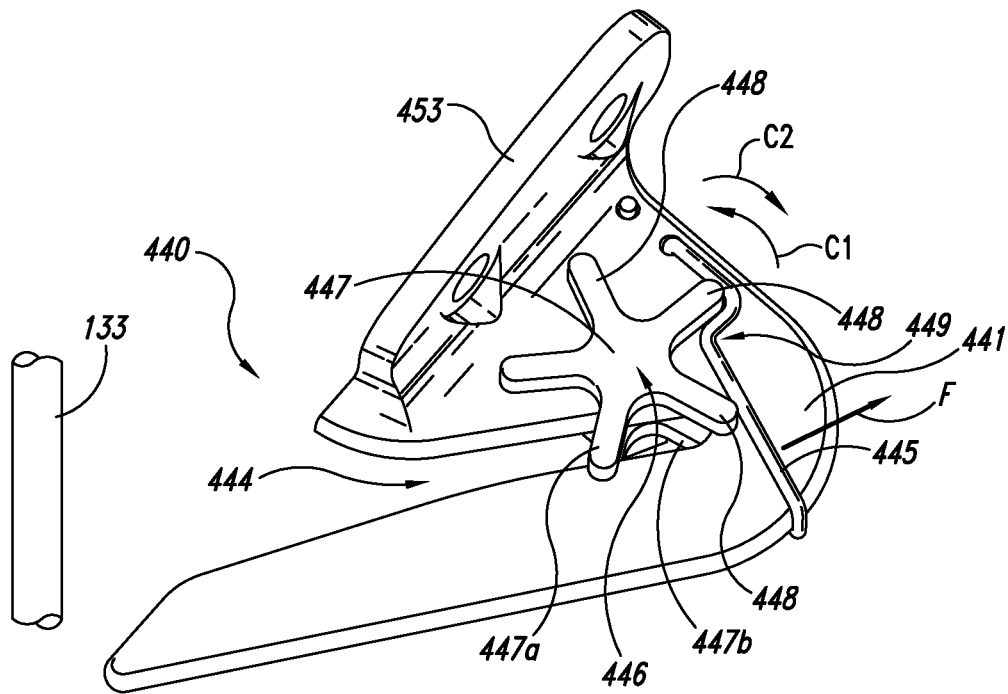


Fig. 4

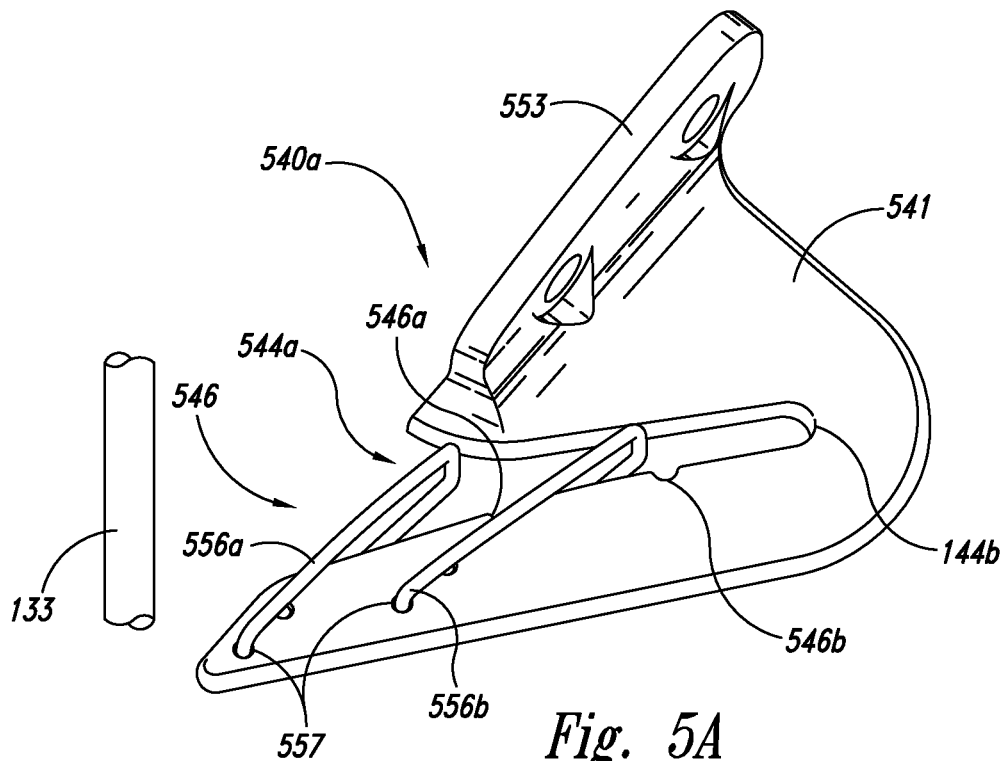


Fig. 5A



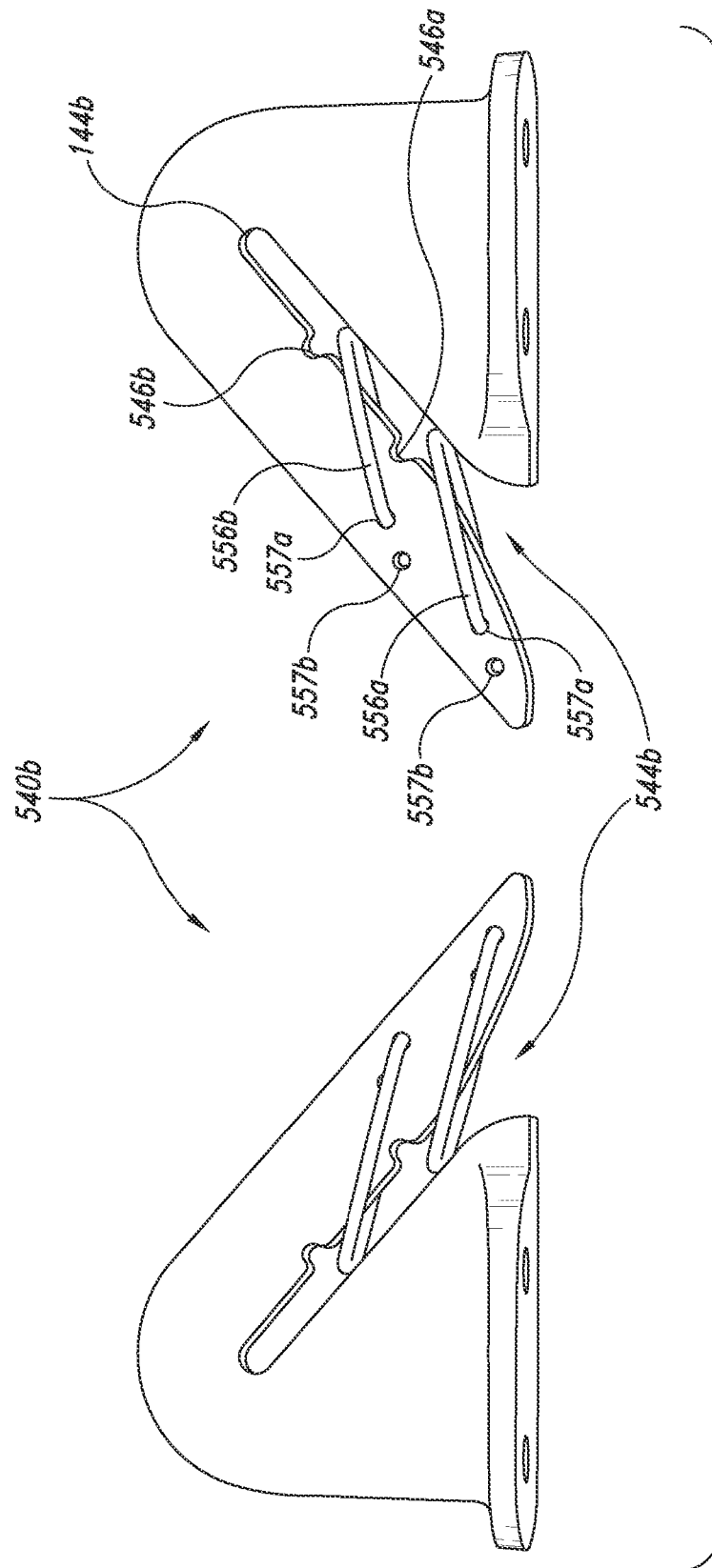
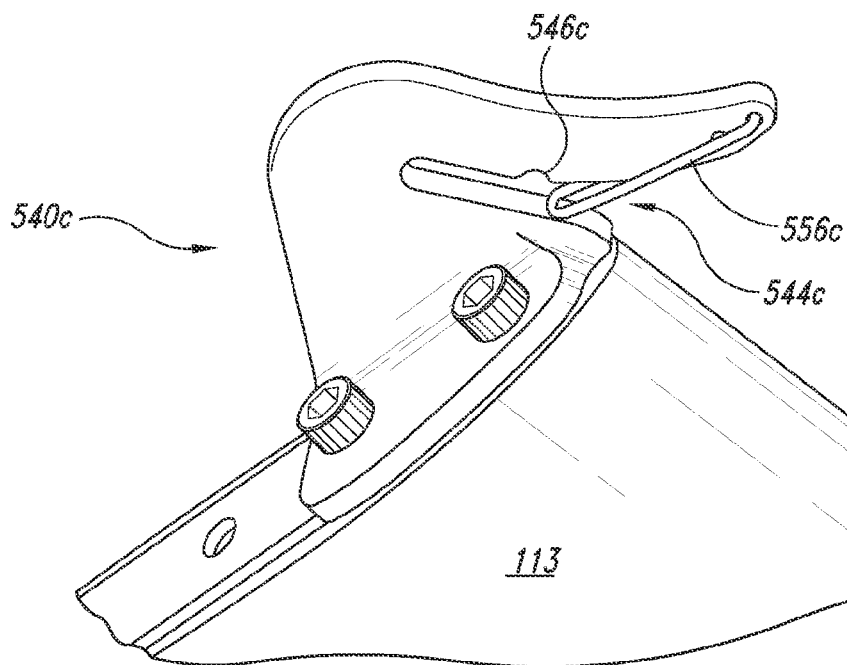
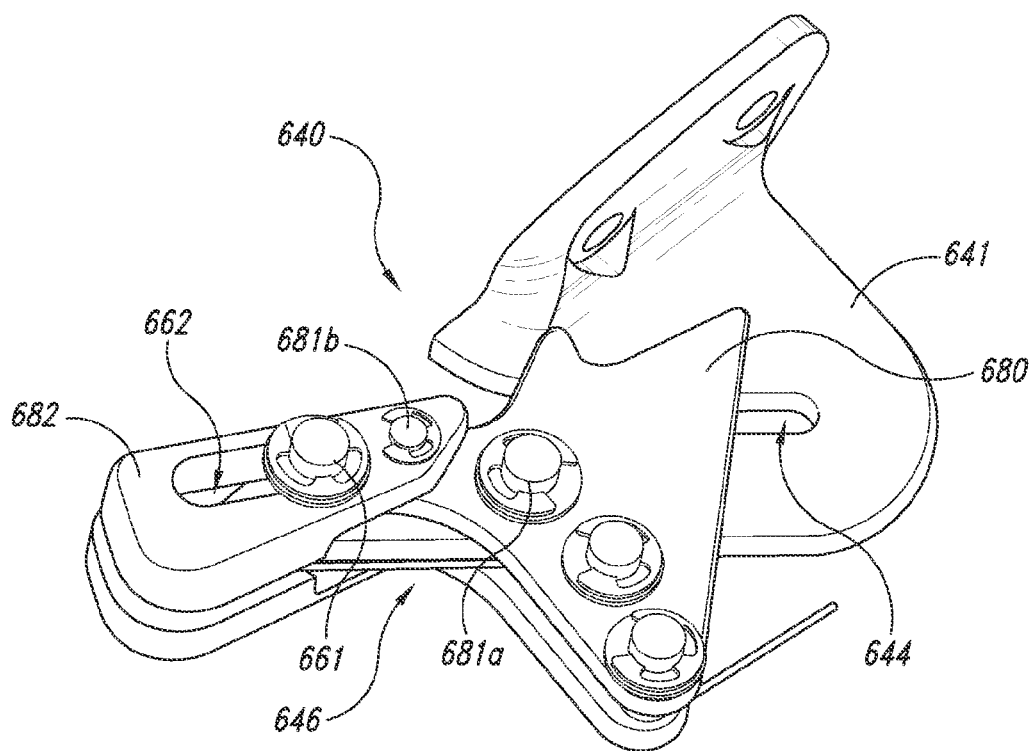


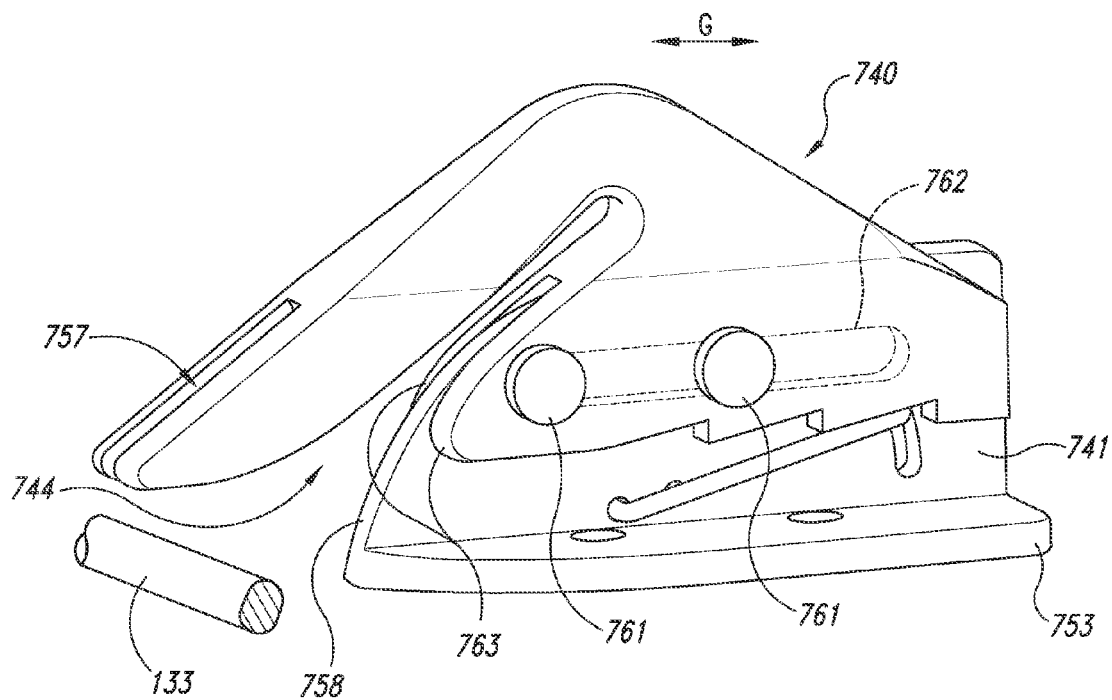
Fig. 5B



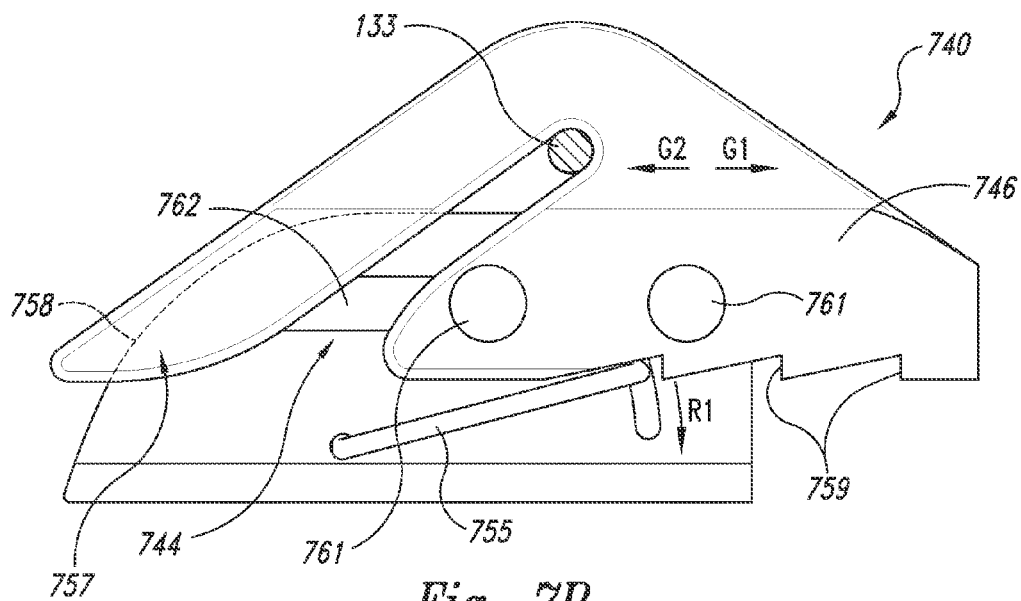
*Fig. 5C*



*Fig. 6*



*Fig. 7A*



*Fig. 7B*

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# LINE CAPTURE DEVICES FOR UNMANNED AIRCRAFT, AND ASSOCIATED SYSTEMS AND METHODS

## CROSS-REFERENCE TO RELATED APPLICATION

The present application is a divisional application of U.S. patent application Ser. No. 13/483,330, filed May 30, 2012, which is a continuation of International Patent Application No. PCT/US2011/053534, filed Sep. 27, 2011, which claims priority to U.S. Provisional Patent Application No. 61/386,956, filed Sep. 27, 2010 each of which is incorporated herein in its entirety by reference.

## TECHNICAL FIELD

The present disclosure describes line capture devices for unmanned aircraft, and associated systems and methods.

## BACKGROUND

Unmanned aircraft or air vehicles (UAVs) provide enhanced and economical access to areas where manned flight operations are unacceptably costly and/or dangerous. For example, unmanned aircraft outfitted with remotely controlled cameras can perform a wide variety of surveillance missions, including spotting schools of fish for the fisheries industry, monitoring weather conditions, providing border patrols for national governments, and providing military surveillance before, during and/or after military operations.

Existing unmanned aircraft systems suffer from a variety of drawbacks. For example, existing unmanned aircraft systems (which can include the aircraft itself along with launch devices, recovery devices, and storage devices) typically require substantial space. Accordingly, these systems can be difficult to install and operate in cramped quarters, such as the deck of a small fishing boat, land vehicle, or other craft. Another drawback with some existing unmanned aircraft is that, due to small size and low weight, they can be subjected to higher acceleration and deceleration forces than larger, manned air vehicles and can accordingly be prone to damage, particularly when manually handled during recovery and launch operations in hostile environments, such as a heaving ship deck. Yet another drawback with some existing unmanned aircraft systems is that they may not be suitable for recovering aircraft in tight quarters, without causing damage to either the aircraft or the platform from which the aircraft is launched and/or recovered.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A-1B illustrate an apparatus configured to recover unmanned aircraft in accordance with embodiments of the disclosure.

FIGS. 2A-2B are enlarged illustrations of a capture device in the process of capturing an unmanned aircraft in accordance with an embodiment of the disclosure.

FIGS. 3A-3D illustrate an embodiment of the line capture device shown in FIGS. 2A-2B, and components of the device.

FIG. 4 illustrates a line capture device having a multi-component rotor in accordance with an embodiment of the disclosure.

FIG. 5A-5C illustrate line capture devices having capture gates in accordance with further embodiments of the disclosure.

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FIG. 6 illustrates a line capture device having a sliding linkage gate in accordance with an embodiment of the disclosure.

FIGS. 7A-7B illustrate a line capture device having a translating retainer in accordance with an embodiment of the disclosure.

## DETAILED DESCRIPTION

FIGS. 1A-1B illustrate overall views of apparatuses and methods for capturing unmanned aircraft in accordance with embodiments of the disclosure. Beginning with FIG. 1A, a representative unmanned aircraft 110 can be captured by an aircraft handling system 100 positioned on a support platform 101. In one embodiment, the support platform 101 can include a boat, ship, or other water vessel 102. In other embodiments, the support platform 101 can include other structures, including a building, a truck or other land vehicle, or an airborne vehicle, such as a balloon. In many of these embodiments, the aircraft handling system 100 can be configured solely to retrieve the aircraft 110 or, in particular embodiments, it can be configured to both launch and retrieve the aircraft 110. The aircraft 110 can include a fuselage 111 and wings 113 (or a blended wing/fuselage), and is propelled by a propulsion system 112 (e.g., a piston-driven propeller).

Referring now to FIG. 1B, the aircraft handling system 100 can include a recovery system 130 integrated with a launch system 170. In one aspect of this embodiment, the recovery system 130 can include an extendable boom 131 having a plurality of segments 132. The boom 131 can be mounted on a rotatable base 136 or turret for ease of positioning. The segments 132 are initially stowed in a nested or telescoping arrangement and are then deployed to extend outwardly as shown in FIG. 1B. In other embodiments, the extendable boom 131 can have other arrangements, such as a scissors arrangement, a parallel linkage arrangement or a knuckle boom arrangement. In any of these embodiments, the extendable boom 131 can include a recovery line 133 extended by gravity or other forces. In one embodiment, the recovery line 133 can include 0.25 inch diameter polyester rope, and in other embodiments, the recovery line 133 can include other materials and/or can have other dimensions (e.g., a diameter of 0.3125 inch). In any of these embodiments, a spring or weight 134 at the end of the recovery line 133 can provide tension in the recovery line 133. The aircraft handling system 100 can also include a retrieval line 135 connected to the weight 134 to aid in retrieving and controlling the motion of the weight 134 after the aircraft recovery operation has been completed. In another embodiment, a different recovery line 133a (shown in dashed lines) can be suspended from one portion of the boom 131 and can attach to another point on the boom 131, in lieu of the recovery line 133 and the weight 134.

In one aspect of this embodiment, the end of the extendable boom 131 can be positioned at an elevation E above the local surface (e.g., the water shown in FIG. 1B), and a distance D away from the nearest vertical structure projecting from the local surface. In one aspect of this embodiment, the elevation E can be about 15 meters and the distance D can be about 10 meters. In other embodiments, E and D can have other values, depending upon the particular installation. For example, in one particular embodiment, the elevation E can be about 17 meters when the boom 131 is extended, and about 4 meters when the boom 131 is retracted. The distance D can be about 8 meters when the boom 131 is extended, and about 4 meters when the boom 131 is retracted. In a further particular aspect of this embodiment, the boom 131 can be configured to carry both a vertical load and a lateral load via the recovery line. For

example, in one embodiment, the boom **131** can be configured to capture an aircraft **110** having a weight of about 30 pounds, and can be configured to withstand a side load of about 400 pounds, corresponding to the force of the impact between the aircraft **110** and the recovery line **133** with appropriate factors of safety.

In any of the foregoing embodiments, the aircraft **110** is captured when it flies into the recovery line **133**. Once captured, the aircraft **110** is suspended from the recovery line by a wing **113**. Further details of apparatuses and methods for capturing the aircraft **110** are described below with reference to FIGS. 2A-7B.

FIG. 2A is a partially schematic, isometric illustration of an outboard portion of the wing **113** of the aircraft **110** shown in FIG. 1B. The wing **113** can include a winglet **116** in the illustrated embodiment but may have no winglets in other embodiments. In one aspect of the illustrated embodiment, the wing **113** includes a leading edge **114** (which can, but need not be swept), an outboard edge **115**, and a line capture device **140** positioned at or near the outboard edge **115**. In other embodiments, each wing **113** can include a plurality of line capture devices **140** located along the span of the wing **113**, or a single line capture device located away from the outboard edge **115**. In any of these embodiments, the line capture device **140** can have a cleat-type configuration. The line capture device **140** can include a line capture device body **141** with a flange **153** that is attached to the wing **113**. In operation, the line capture device **140** engages the recovery line **133** to releasably and securely attach the aircraft **110** to the recovery line **133**. The device **140** can include a line slot **144** positioned in the body **141**, and retainer **146** movably attached to the body **141**. As the aircraft **110** flies toward the recovery line **133** (as indicated by arrow A), the recovery line **133** strikes the wing leading edge **114** and causes the aircraft **110** to yaw toward the recovery line **133**, which then slides outboard along the leading edge **114** toward the line capture device **140** (as indicated by arrow B). The recovery line **133** then passes into the line slot **144** and is retained in the line slot **144** by the retainer **146**, as described in greater detail below. In other embodiments, the retainer can operate in other manners to secure the recovery line **133** in the line slot **144**.

If the aircraft **110** is not properly aligned with the recovery line **133** during its approach, the recovery line **133** may strike the line capture device **140** instead of the leading edge **114**. In one embodiment, the body **141** includes a body leading edge **160** that is swept aft so as to deflect the recovery line **133** away from the aircraft **110**. This can prevent the line **133** from fouling and can reduce the yawing moment imparted to the aircraft **110**, allowing the aircraft **110** to recover from the missed capture and return for another capture attempt.

During capture, the recovery line **133** travels outboard along the wing leading edge **114** to position the recovery line **133** at the line slot **144** of the line capture device **140**. In one aspect of this embodiment, the retainer **146** includes a rotor **147** that rotates relative to the body **141** within a rotor slot **145** via a pivot joint (e.g., a pin or axle **149**). The rotor **147** includes multiple rotor arms **148**, four of which are shown in FIG. 2A as a first rotor arm **148a**, a second rotor arm **148b**, a third rotor arm **148c**, and a fourth rotor arm **148d**. Before the line capture device **140** engages the recovery line **133**, one of the rotor arms (e.g. the first rotor arm **148a**) is located transverse to (e.g. perpendicular to) the line slot **144**, and none of the remaining rotor arms extend into the line slot **144**. Accordingly, the first rotor arm **148a** can extend fully or at least partially across the line slot **144**. The rotor **147** can be manually placed in this orientation, or a ratchet mechanism can ensure that the rotor **147** stops at only positions for which

one of the rotor arms **148** extends transverse to the line slot **144**. As the recovery line **133** passes into and along the line slot **144**, it presses against the first rotor arm **148a**, causing the rotor **147** to rotate clockwise, as indicated by arrow C. As the rotor **147** rotates, the recovery line **133** is permitted to pass to the end of the line slot **144**. At the same time, the second rotor arm **148b** rotates into the position previously occupied by the first rotor arm **148a**, as shown in FIG. 2B. In one aspect of this embodiment, the line slot **144** (which can be tapered) has a width that is less than the diameter of the recovery line **133**. Accordingly, the recovery line **133** can be pinched in the line slot **144** as it travels outboard and aft, securing the aircraft **110** to the recovery line **133**. The momentum of the aircraft relative to the recovery line **133** provides the impetus to securely engage the recovery line **133** with the line capture device **140**.

FIGS. 3A-3D illustrate further aspects of a particular embodiment of the line capture device **140** described above with reference to FIGS. 2A-2B. In FIG. 3A, the line capture device **140** is shown from above. The body **141** in this embodiment is formed from two components: a base or base portion **142** and a cover or cover portion **143** that is sealably attached to the base **142**. Both the base **142** and the cover **143** have cut-outs that together define the line slot **144**. The line slot **144** can have an open end **144a** and a closed end **144b**. Both the base **142** and the cover **143** have corresponding flange portions **153a**, **153b**, respectively, that together form the attachment flange **153** used to secure the line capture device **140** to the aircraft **110** (FIG. 2B). The central portions of the base **142** and the cover **143** are spaced apart from each other to define, at least in part, the rotor slot **145** in which the rotor **147** rotates. Accordingly, the rotor **147** can be protected from environmental factors and can be held in place by the base **142** and the cover **143** so as not to bend or deflect significantly as the recovery line **133** (FIG. 2B) impinges on the rotor arms **148**. The cover **143** includes a ratchet device, e.g., a ratchet tab **164** that can be bounded by a milled or otherwise formed groove. Prior to first use, the ratchet tab **164** is bent downwardly (into the plane of FIG. 3A) toward the base **142**. The tab **164** can accordingly be sloped inwardly into the rotor slot **145**, in a direction generally tangential to the direction of rotation of the rotor **147**. As a result, the ratchet tab **164** can resist but allow clockwise rotation by the rotor **147**, and prevent significant counterclockwise rotation. In this manner, the ratchet tab **164** can allow the rotor **147** to turn as it captures the recovery line **133**, and prevent the rotor **147** from releasing the recovery line **133** until an operator actively manipulates the device **140**.

FIG. 3B is a top isometric view of an embodiment of the base **142**. As described above, the base **142** includes a cut-out that defines, in part, the line slot **144**, and a cut-out that defines, in part, the rotor slot **145**. The base **142** also includes a pin aperture **151** that receives one end of the pin or axle **149** shown in FIG. 2A. The base **142** can also include features that aid in aligning and securing it to the cover **143** (FIG. 3A). For example, the base **142** can include multiple alignment slots **152**, shown in FIG. 3B as a first alignment slot **152a**, a second alignment slot **152b**, and a third alignment slot **152c**. The alignment slots **152a-152c** align with corresponding tabs carried by the cover **143**, as discussed further below with reference to FIG. 3C. In one aspect of an embodiment shown in FIG. 3B, at least one of the alignment slots (e.g. the second alignment slot **152b**) is tapered to prevent the corresponding tab from pulling out of the slot in a direction generally normal to the plane of FIG. 3B. The base **142** can also include a release aperture **165** or other feature that allows the operator to release the recovery line **133** (FIG. 3A) after the capture operation is complete. In one embodiment, the release aper-

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ture 165 is positioned to allow the operator to insert a tool into the rotor slot 145. The tool presses outwardly against the ratchet tab 164 (FIG. 3A) so that the operator can rotate the rotor counterclockwise and release the recovery line 133.

FIG. 3C is a bottom isometric view of the cover 143, illustrating the corresponding tabs 154 (shown as a first tab 154a, a second tab 154b, and a third tab 154c) that are received in the alignment slots 152a-152c described above with reference to FIG. 3B. The second tab 154b has tapered sides that slide into the second alignment slot 152b and that resist relative motion normal to the plane at FIG. 3C between the cover 143 and the base 142. The cover 143 also includes a pin aperture 151 that receives one end of the axle or pin 149, thus securing the pin between the cover 143 and the base 142 and capturing the rotor 147 in the rotor slot 145.

FIG. 3D is an isometric illustration of the rotor 147. The rotor 147 includes a hub 150, the four rotor arms 148a-148d, and a pin aperture 151 that receives the pin 149 described above. In a particular embodiment, the rotor 147 includes four rotor arms to ensure that only one rotor arm is positioned in the corresponding line slot 144 at a time. In other embodiments, for example, if the line slot has other shapes or geometries, the rotor 147 can include other numbers of rotor arms 148. One representative example is described further below with reference to FIG. 4.

FIG. 4 is a partially schematic, isometric illustration of a line capture device 440 configured in accordance with another embodiment of the disclosure. In one aspect of this embodiment, the line capture device 440 includes a body 441 and a flange 453 for securing the body 441 to the aircraft 110 (FIG. 1A). The body 441 has a line capture slot 444 that operates in generally the same manner described above with reference to FIGS. 2A-3D. The line capture device 440 further includes a retainer 446 having a rotor 447 that rotates relative to the body 441 via a pin or axle (not visible in FIG. 4). The rotor 447 can include a first or upper rotor portion 447a positioned adjacent to an upward facing surface of the body 441, and a second or lower portion 447b positioned adjacent the opposite face of the body 441. The first and second portions 447a, 447b are connected to each other via the pin, which passes through a corresponding pin aperture in the body 441. Thus, unlike the arrangement described above with reference to FIGS. 3A-3D, the line capture device 440 has two rotor portions with the body 441 positioned in between, rather than a single rotor portion positioned between a body and a cover.

The retainer 446 shown in FIG. 4 can further include a ratchet device that includes a ratchet spring 445 shaped to engage any of the rotor arms 448 carried by the rotor 447. The ratchet spring 445 is shaped to provide a biasing force directed toward the left of FIG. 4, and, as shown in FIG. 4, bears on two of the rotor arms 448 simultaneously. Accordingly, the ratchet spring 445 can engage the ends of the rotor arms 448. The ratchet spring 445 can include a dog-leg or jog 449 that bears against the side of one of the arms 448 to restrict or prevent the rotor 447 from rotating counterclockwise. This arrangement keeps the rotor 447 in position until the recovery line 133 strikes it and rotates it in a first direction, e.g., counterclockwise (as indicated by arrow C1) as the recovery line 133 passes along the length of the line capture slot 444. The rotor 447 is at least restricted from rotating in a second direction, e.g., clockwise (as indicated by arrow C2). Because the rotor 447 is positioned toward the end of the line capture slot 444, it can include more than four rotor arms 448 (e.g. five rotor arms 448) with only one of the rotor arms 448 positioned across the line capture slot 444.

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One feature of the line capture device 440 shown in FIG. 4 is that the ratchet arrangement keeps the recovery line 133 from being pulled out of the line capture slot 444 even if the recovery line 133 folds during the capture operation. Another feature of this embodiment is that it requires no setup prior to use. That is, the ratchet spring 445 operates to always place the rotor 447 in a position suitable for capture. Still a further feature is that the line capture device 440 can be easily disengaged from the recovery line 133, e.g., by (a) pushing the ratchet spring 445 away from the rotor 447 (as indicated by arrow F), thus allowing the rotor 447 to rotate freely in a clockwise direction C2, and then (b) moving the recovery line 133 out of the line capture slot 444.

FIG. 5A is a partially schematic, top isometric illustration of a line capture device 540a configured in accordance with yet another embodiment of the disclosure. In this embodiment, the line capture device 540a includes a body 541 having a line slot 544a and a flange 553. The line capture device 540a also include a retainer 546 that in turn includes multiple independently operable gates 556 (two are shown in FIG. 5 as a first gate 556a and a second gate 556b). The gates 556 can include flexible but resilient wires or wire-shaped elements that are attached to the body 541 so as to be biased to positions that extend across the line slot 544a. As the recovery line 133 passes into the line slot 544a, it can push one or both of the gates 556a, 556b out of the way, and allow the gate(s) to spring back into position, thus securing the recovery line 133 within the line slot 544a. Because the gates 556a, 556b are independently operable, they provide a redundancy feature. As discussed above, the gates 556a, 556b can be formed from a suitable high strength wire, and can be rigidly connected to the body 541. Accordingly, the gates 556 twist about an axis generally perpendicular to the plane of FIG. 5A when impinged upon by the recovery line 133. The body 541 can include two receptacles 546a, 546b that receive the ends of the corresponding gates 556a, 556b to allow each gate to (successively) completely clear the line slot 544a as the recovery line 133 passes by. The spring force of the wire (or other resilient material forming the gates 556a, 556b) in torsion causes the gates to return to the positions shown in FIG. 5A after the recovery line 133 has passed into the line slot 544a. The body 541 can include through-holes 557, with coaxial openings in the oppositely facing surfaces of the body 541, that receive the proximal ends of the wire-shaped elements forming the gates 556, for securing the elements to the body. The arrangement shown in FIG. 5A has the advantage of simplicity due to the relatively small number of parts it requires.

FIG. 5B illustrates two line capture devices 540b (one for a right wing 113 and the other for a left wing 113), each having a configuration in accordance with another embodiment of the disclosure. In this particular embodiment, the line capture devices 540b operate generally similar to the line capture device 540a described above with reference to FIG. 5A. In addition, the line capture devices 540b include a line slot 544b that is narrow in the region between the first and second gates 556a, 556b. Accordingly, it is expected that this arrangement will more securely capture a recovery line that passes the first gate 556a but not the second gate 556b. In the embodiments shown in FIGS. 5A and 5B, the gates 556a, 556b can be spaced apart from each other by a distance sufficient to accommodate the capture line 133 (FIG. 5A), and the second gate 556b can be spaced apart from the closed end 144b of the line slot 544a, 544b by a distance sufficient to accommodate the capture line 133. In a particular aspect of an embodiment shown in FIG. 5B, the proximal ends of the wire-shaped elements forming the gates 556a, 556b can be

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offset, and can be received in corresponding offset holes **557a**, **557b** in the body **541**. The holes can be through holes or can extend part-way through the opposing surfaces of the body **541**.

FIG. 5C illustrates another line capture device **540c**. The line capture device **540c** has a single gate **556c** that is structurally similar to the first and second gates **556a**, **556b** described above, and that is attached to the corresponding body **541** in a generally similar manner, so as to be biased to a position that extends across a corresponding line slot **544c**. A receptacle **546c** along the edge of the line slot **544c** receives the end of the gate **556c** as the gate opens. The foregoing arrangement has the advantage of being simpler than the arrangements described above with reference to FIGS. 5A and 5B. Conversely, the arrangements described above with reference to FIGS. 5A and 5B can provide redundancy and an additional level of security for capturing the recovery line **133**.

FIG. 6 illustrates still another line capture device **640** that includes a body **641** having a line slot **644**. The body **641** carries a retainer **646** that slides relative to the body **641** during capture. In particular, the retainer **646** can include a strike plate **680** and a closing tab **682**. The strike plate **680** is pivotably connected to the body **641** at a first pivot joint **681a**, and is pivotably connected to the closing tab **682** at a second pivot joint **681b**. The strike plate **680** also carries a guide pin **661** that is received in a corresponding guide slot **662** of the closing tab **682**. In operation, the closing tab **682** can guide the recovery line **633** to hit the strike plate **680**, which can be spring-loaded. Upon being struck by the recovery line **133**, the strike plate **680** rotates clockwise about the first pivot joint **681a**, opening the line slot **644** and allowing the recovery line **633** to pass into the line slot **644**. As the strike plate **680** rotates, it pulls the closing tab **682** across the entrance of the line slot **644** via the second pivot joint **681b**. The motion of the closing tab **682** is guided by the guide pin **661** received in the guide slot **662**.

FIGS. 7A and 7B illustrate still another line capture device **740** in accordance with an embodiment of the disclosure. Referring first to FIG. 7A, the line capture device **740** includes a body **741** carrying a mounting flange **753**. The body **741** also includes a guide slot **762**. A retainer **746** has two ears **763**, each of which extends around an oppositely facing side of the body **741**. One or more guide pins **761** (e.g., two) connect the two ears **763** together and pass through the guide slot **762**. Accordingly, the retainer **746** can translate back and forth as indicated by arrow G relative to the body **741**. The retainer **746** includes a line slot **744** into which the recovery line **133** passes during a recovery/capture process. The retainer **746** also includes a retainer slot **757** that receives a corresponding body tab **758** of the body **741** when the recovery line **133** has been captured, as discussed further below with reference to FIG. 7B.

FIG. 7B illustrates the line capture device **740** after it has successfully engaged the recovery line **133**. The recovery line **133** has passed to the end of the line slot **744**, and the force of the recovery line **133** on the retainer **746** has driven the retainer to the right as indicated by arrow G1, with guidance provided by the guide pins **761** in the guide slot **762**. Once in this closed position, a ratchet spring **755** carried by the body **741** engages one of the ratchet teeth **759** carried by the retainer **746** to prevent the retainer from moving to the left, which would allow the recovery line **133** to escape from the line slots **744**. As the retainer **746** moves to the right as indicated by arrow G1, the body tab **758** passes into the retainer slot **757**. This action prevents the retainer **746** from bending or deflecting outwardly from the plane of FIG. 7B,

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which might otherwise allow the recovery line **133** to pass out at the slot **744**. To disengage the recovery line **133**, the operator can rotate the ratchet spring as indicated by arrow R1 and slide the retainer **746** as indicated by arrow G2.

One feature of the embodiments described above with reference to FIGS. 1A-7B is that the line capture devices can not only capture the recovery line, but also resist or account for a tendency of the recovery line to disengage from the line slot as the aircraft twists and rotates during the capture maneuver. Accordingly, embodiments of the present disclosure are expected to secure the aircraft with a potentially greater degree of reliability than other devices.

From the foregoing, it will be appreciated that specific embodiments of the disclosure have been described herein for purposes of illustration, but that various modifications may be made without deviating from the disclosure. For example, the slots for capturing the recovery line can have other orientations, shapes, and/or sizes in other embodiments. The devices used to retain the recovery lines within the slots can include other arrangements to keep them biased in the closed position. Such arrangements can include other types of springs. The devices can include other components or other arrangements of components in other embodiments. The retainers can move between first positions (restricting access to the line slot) and second positions (allowing access to the line slot) that are different than those described above. The rotor rotation directions can be different than those expressly disclosed above. In many of these embodiments, the recovery line forces the retainer to move from the first position to the second position. In other embodiments, other forces can cause this motion. The boom and/or other elements supporting the recovery line can have other configurations in other embodiments.

Certain aspects of the disclosure described in the context of particular embodiments may be combined or eliminated in other embodiments. For example, the line capture devices were described in the context of a representative unmanned air vehicle shown in FIGS. 1A and 1B. In other embodiments, any of the foregoing line capture devices can be mounted on suitable aircraft having other configurations. The alignment slots and tabs described above in the context of the base and cover, respectively, in FIGS. 3B and 3C can be "swapped" and instead placed on the cover and base, respectively. Further, while advantages associated with certain embodiments have been described in the context of those embodiments, other embodiments may also exhibit such advantages and not all embodiments need necessarily exhibit such advantages to fall within the scope of the present disclosure. Accordingly, the disclosure can encompass other embodiments not expressly described or shown herein.

We claim:

1. An aircraft system, comprising:

- a line capture device body having a line slot, the line slot having an open end and a closed end;
- a retainer positioned proximate to the line slot, the retainer including a rotor having a plurality of rotor arms positioned to extend at least partially across the line slot as the rotor rotates relative to the body;
- a joint rotatably coupling the rotor to the body; and
- a ratchet device operably coupled to the rotor to allow the rotor to rotate in a first direction and at least restrict the rotor from rotating in a second direction opposite the first.

2. The system of claim 1 wherein the line capture device body includes a base portion and a cover portion carried by the base portion, with at least part of the base portion spaced apart from at least part of the cover portion to define, at least

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in part, a rotor slot, and wherein the rotor is rotatably positioned between the base portion and the cover portion in the rotor slot.

3. The system of claim 2 wherein the ratchet device includes a ratchet tab projecting inwardly into the rotor slot from at least one of the base portion and the cover portion, the ratchet tab being sloped inwardly into the rotor slot.

4. The system of claim 2 wherein at least one of the base portion and the cover portion includes a tab and wherein the other of the base portion and the cover portion includes an alignment slot positioned to receive the tab and resist relative motion between the cover portion and the base portion.

5. The system of claim 1 wherein the line capture device body has a first surface and a second surface facing away from the first surface, and wherein the rotor is a first rotor positioned adjacent to the first surface, and wherein the system further comprises a second rotor positioned adjacent to the second surface and rotatably coupled to the line capture device body, the second rotor having a plurality of rotor arms positioned to extend at least partially across the line slot as the second rotor rotates relative to the line capture device body.

6. The system of claim 1 wherein individual rotor arms have ends positioned radially outwardly from a pin, and wherein the ratchet device includes a spring positioned to successively engage with the ends of corresponding individual rotor arms as the rotor rotates relative to the line capture device body.

7. The system of claim 1 wherein the line slot is tapered between the open end and the closed end.

8. The system of claim 1, further comprising an aircraft having a fuselage and a wing, and wherein the line capture device body is attached to the wing.

9. The system of claim 8 wherein the line capture device body has a leading edge, and wherein the leading edge is swept aft relative to the fuselage.

10. The system of claim 8 wherein the line capture device body is positioned away from an outboard edge of the wing.

11. The system of claim 1, further comprising:

a recovery line; and

a support carrying the recovery line.

12. An aircraft system, comprising: a line capture device having a line capture device body, a rotor rotatably attached to the line capture device body, and a ratchet device configured to restrict a first direction of rotation of the rotor relative to the line capture device body;

wherein the rotor comprises a hub and a plurality of rotor arms extending outwardly from the hub,

wherein the line capture device body includes a line slot configured to receive a recovery line, and

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wherein at least a portion of the rotor is positioned to extend at least partially across the line slot when the rotor is in a first orientation relative to the line capture device body.

13. The system of claim 12 wherein the line capture device body includes a base portion, a cover portion carried by the base portion, and a rotor slot defined at least in part by a space between a surface of the base portion and a surface of the cover portion, and wherein the rotor is positioned at least partially within the rotor slot.

14. The system of claim 13 wherein at least one of the base portion and the cover portion includes a tab and wherein the other of the base portion and the cover portion includes an alignment slot positioned to receive the tab.

15. The system of claim 12 wherein the ratchet device includes a ratchet tab bent toward an interior opening of the line capture device body.

16. The system of claim 12 wherein:

the line capture device body has a first surface and a second surface facing away from the first surface;

the rotor includes a first rotor portion positioned adjacent to the first surface and a second rotor portion positioned adjacent to the second surface; and wherein

the system further comprises an axle connecting the first rotor portion to the second rotor portion.

17. The system of claim 12 wherein the ratchet device includes an elongated spring positioned to engage at least a portion of the rotor.

18. The system of claim 12 wherein the line capture device is a first line capture device, and wherein the system further comprises a second line capture device.

19. An aircraft system, comprising: a line capture device body attached to a wing of an aircraft and having a line slot with an open end and a closed end, the line slot being configured to receive a recovery line;

a rotor comprising a hub and a plurality of rotor arms extending outwardly from the hub, the rotor rotatably coupled to the line capture device body, at least a portion of the rotor extending at least partially across the line slot when the rotor is in at least one orientation relative to the line capture device body; and

a ratchet device; wherein

the rotor is positioned to rotate in a first direction when the recovery line presses against the portion of the rotor, and wherein

the ratchet device is positioned to allow the rotor to rotate in the first direction and limit rotation of the rotor in a second direction opposite the first direction.

\* \* \* \* \*



UNITED STATES PATENT AND TRADEMARK OFFICE  
**CERTIFICATE OF CORRECTION**

PATENT NO. : 9,340,301 B2  
APPLICATION NO. : 14/569443  
DATED : May 17, 2016  
INVENTOR(S) : Matthew Robert Dickson et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the specification

In column 1, line 65, delete "FIG." and insert -- FIGS. --, therefor.

In column 4, line 61, delete "FIG. 33," and insert -- FIG. 3B, --, therefor.

In column 5, line 9, delete "FIG. 3B," and insert -- FIG. 3B. --, therefor.

In column 7, line 55, delete "133," and insert -- 133. --, therefor.

In column 7, line 59, delete "762," and insert -- 762. --, therefor.

In column 7, line 64, delete "744," and insert -- 744. --, therefor.

Signed and Sealed this  
Twentieth Day of September, 2016



Michelle K. Lee  
*Director of the United States Patent and Trademark Office*